Evaluation and Improvement of Ocean Model Parameterizations for NCEP Operations

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- **Short-term goal:**
  - **Improve ocean model performance in response to tropical cyclone (TC) forcing**
- **Overarching goal:**
  - **Improve performance of the ocean component of coupled hurricane forecast models**
    - **May reduce intensity forecast errors**
- **Procedure:**
  - **Evaluate ocean model simulations against satellite observations and against high-quality operational and targeted ocean observations**

Ocean Model Evaluation (1)

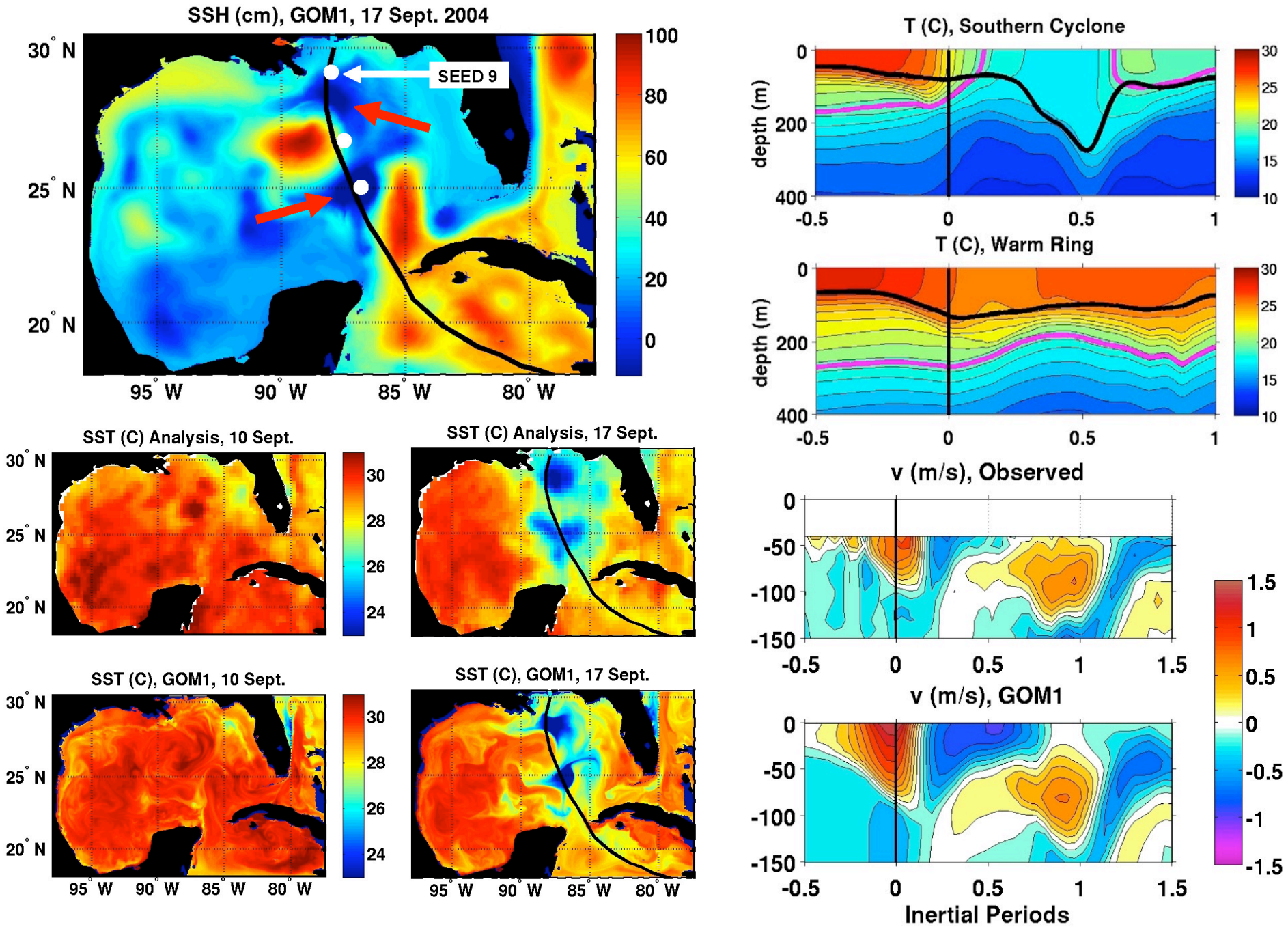
- **Ocean models still have significant errors and biases**
  - **Numerical algorithms**
  - **Sub-grid-scale parameterizations (e.g. vert. mixing)**
  - **Parameterizations of air-sea fluxes**
- **Comprehensive studies are required to understand how these factors combine to degrade ocean model performance**

Ocean Model Evaluation (2)

- HYCOM is chosen as the ocean model
  - Future component of HWRF
  - Contains multiple choices of important numerical algorithms and sub-grid-scale parameterizations
- First comprehensive evaluation effort has been conducted for hurricane Ivan
- Results and recommendations for improving HYCOM performance have been communicated to NOAA/NCEP/EMC

HYCOM Ivan Experiments

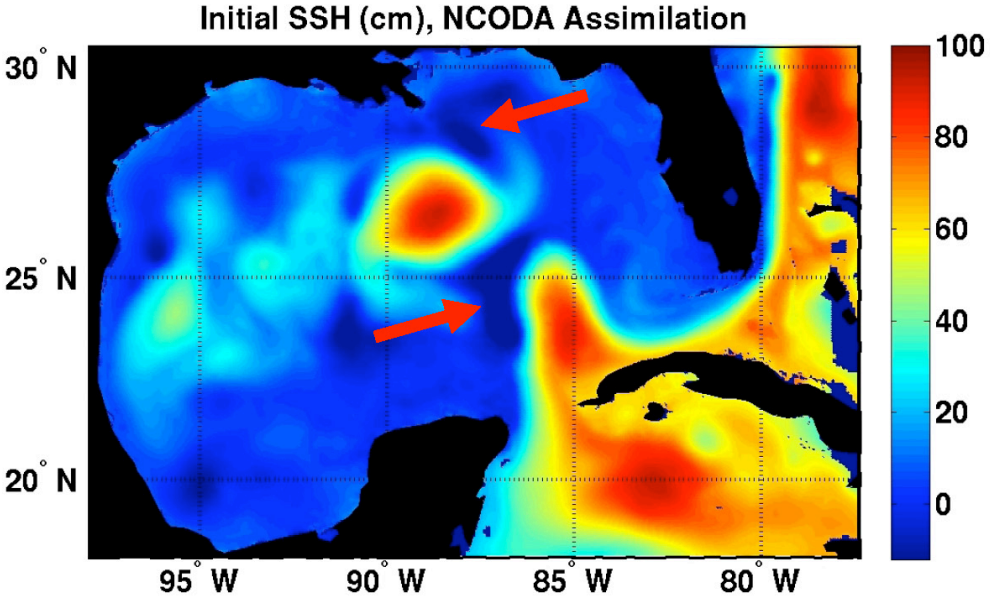
- Run in Gulf of Mexico domain
- Forced by atmospheric model (27-km COAMPS model) blended with the NOAA/AOML/HRD H*WIND analysis to represent wind stress and wind speed within the storm
- Experiments
  - Control using default parameterizations based on prior model experience (but not with TC forcing)
  - Alternate experiments that varied horizontal resolution, vertical resolution, or a single parameterization

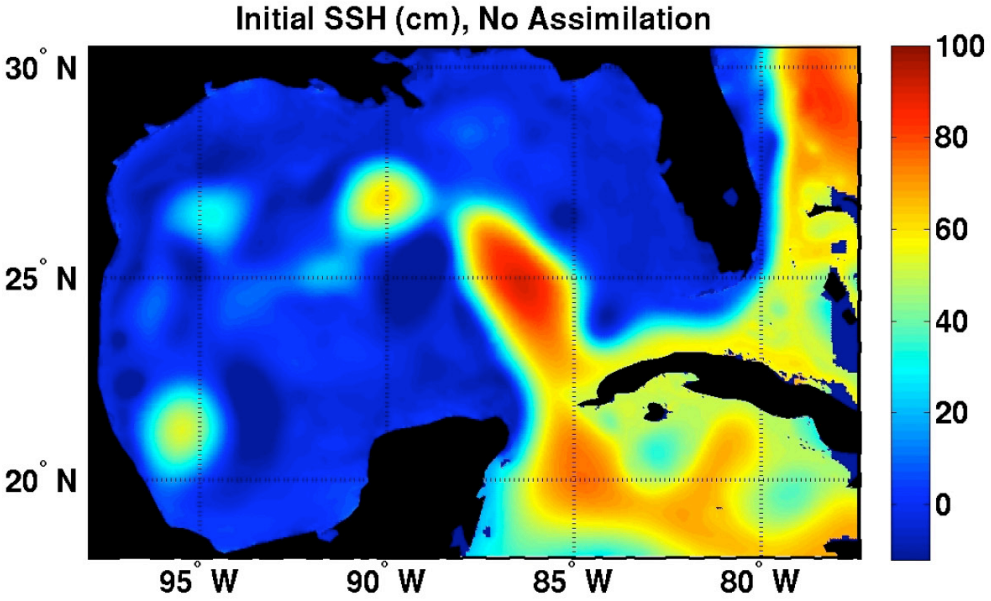

SSH (cm), GOM1, 17 Sept. 2004
SEED 9
30° N
25° N
20° N
95° W
90° W
85° W
80° W
100
80
60
40
20
0
SST (C) Analysis, 10 Sept.
SST (C) Analysis, 17 Sept.
SST (C), GOM1, 10 Sept.
SST (C), GOM1, 17 Sept.
30
28
26
24
T (C), Southern Cyclone
T (C), Warm Ring
depth (m)
0
200
400
-0.5
0
0.5
1
30
25
20
15
10
v (m/s), Observed
v (m/s), GOM1
-50
-100
-150
1.5
1
0.5
0
-0.5
-1
-1.5
Inertial Periods

Hurricane Ivan Experiments (subset)

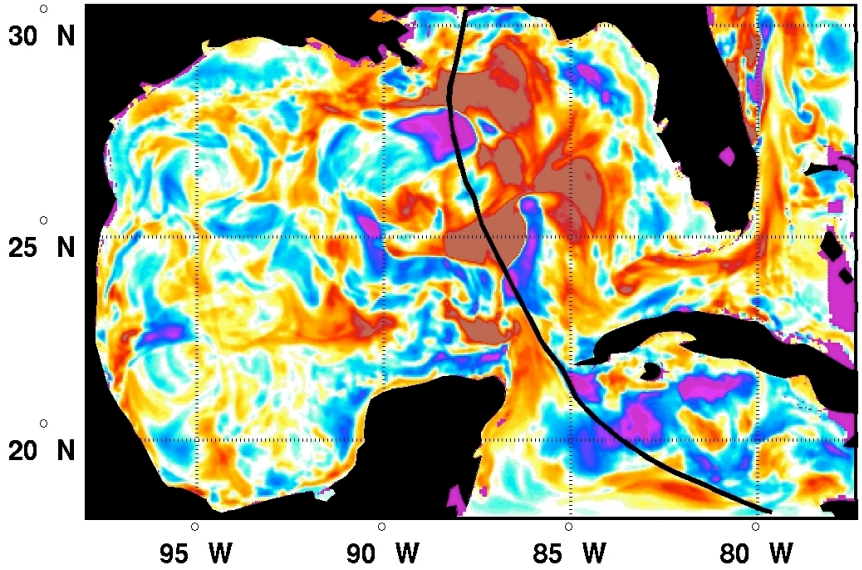
Model Attribute	Control Experiment E1	Alternate Experiments
Horizontal resolution	0.04° Mercator	E2: 0.08° Mercator
Vertical resolution	26 layers, 4-8m in OML	E3: 21 layers, 8-15m in OML E4: 31 layers, 3-5m in OML
Vertical mixing	KPP	E5: MY E6: GISS
C_D	Donelan	E7: Powell E8: Large and Pond E9: Large and Pond (cap) E10: Shay and Jacob
Initialization	Data-assimilative ocean hindcast	E11: Non-assimilative ocean simulation

Evaluated against Reynolds SST analyses and upper-ocean velocity profiles measured at ADCP moorings



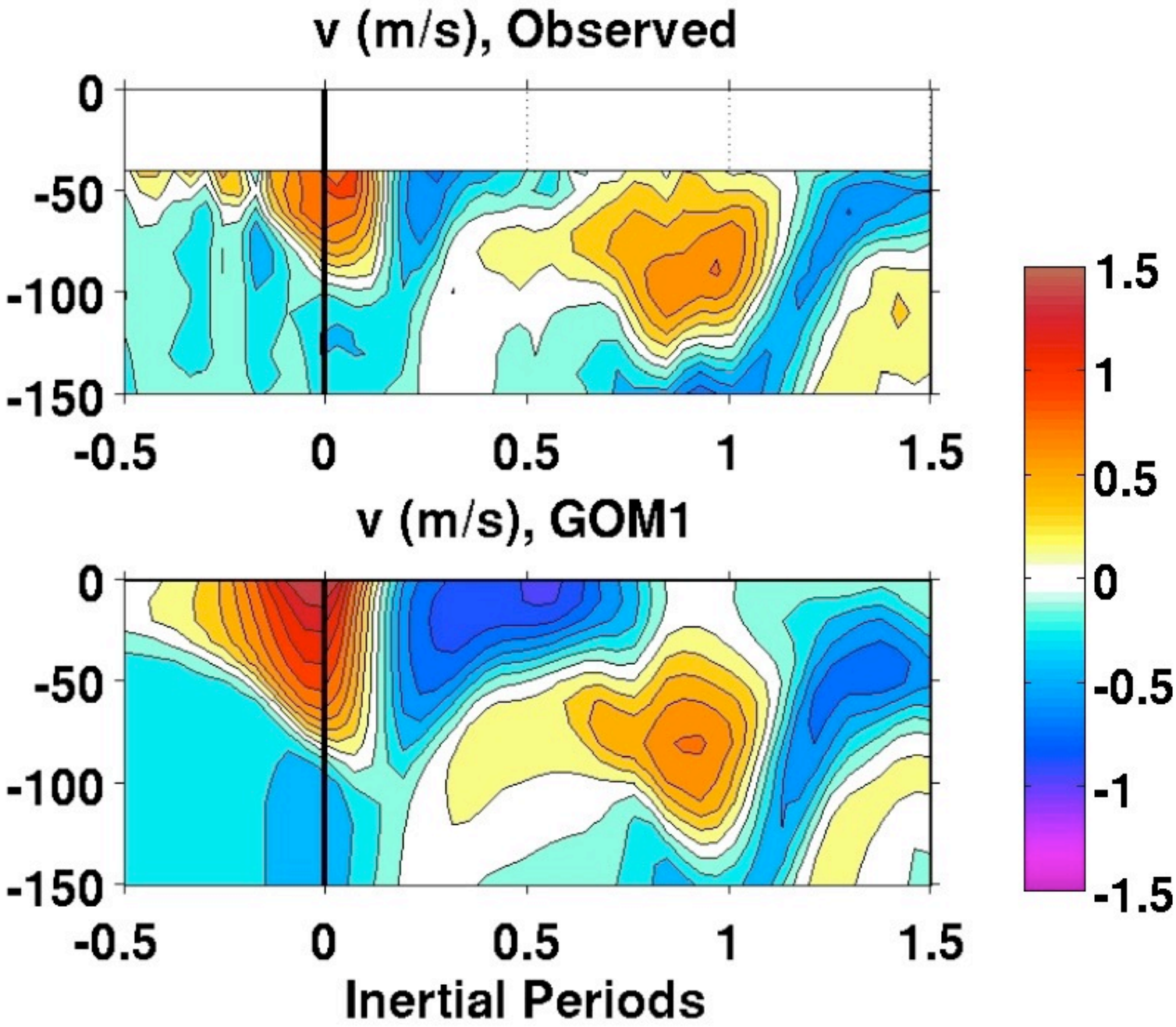


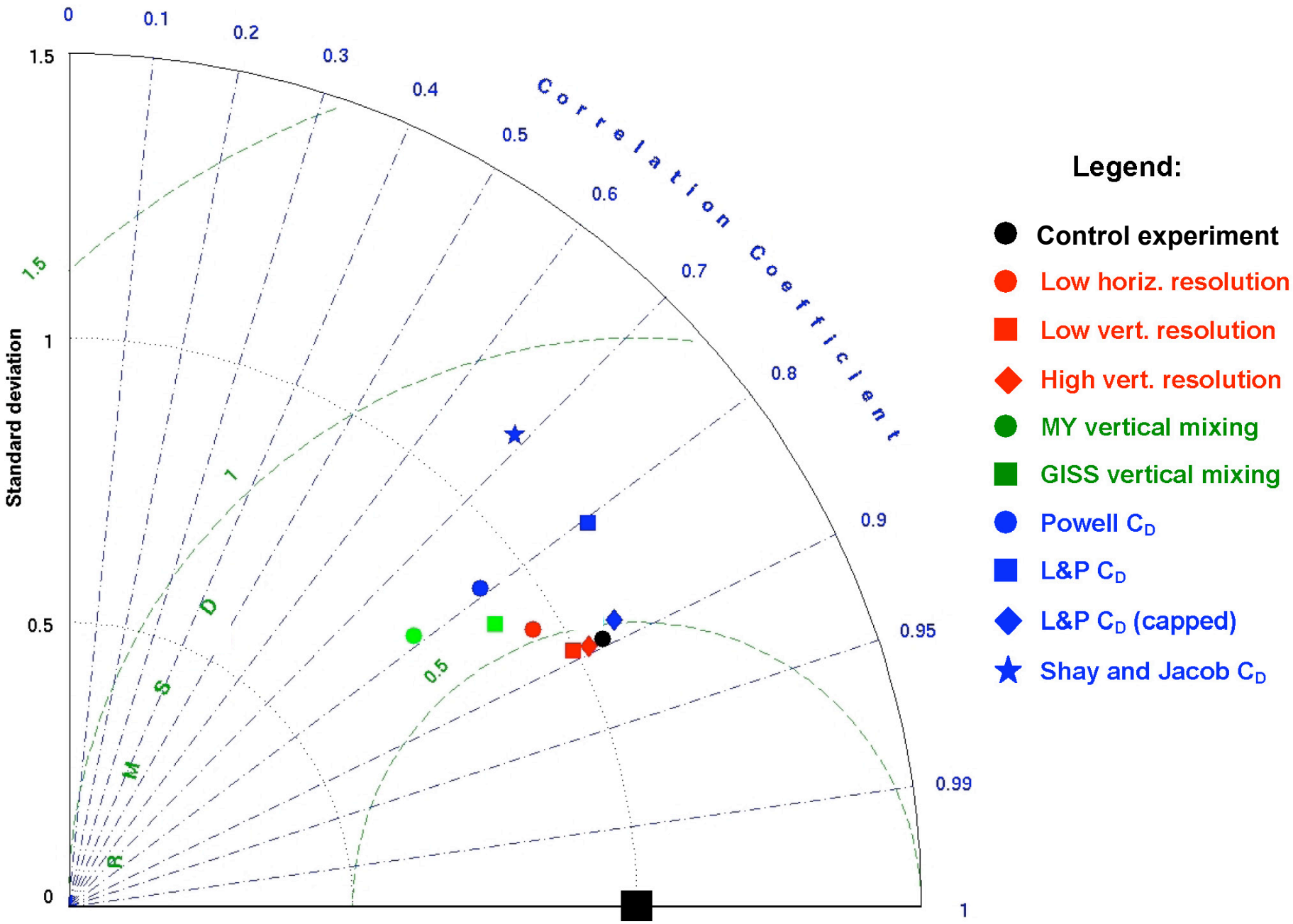
Difference in SST cooling

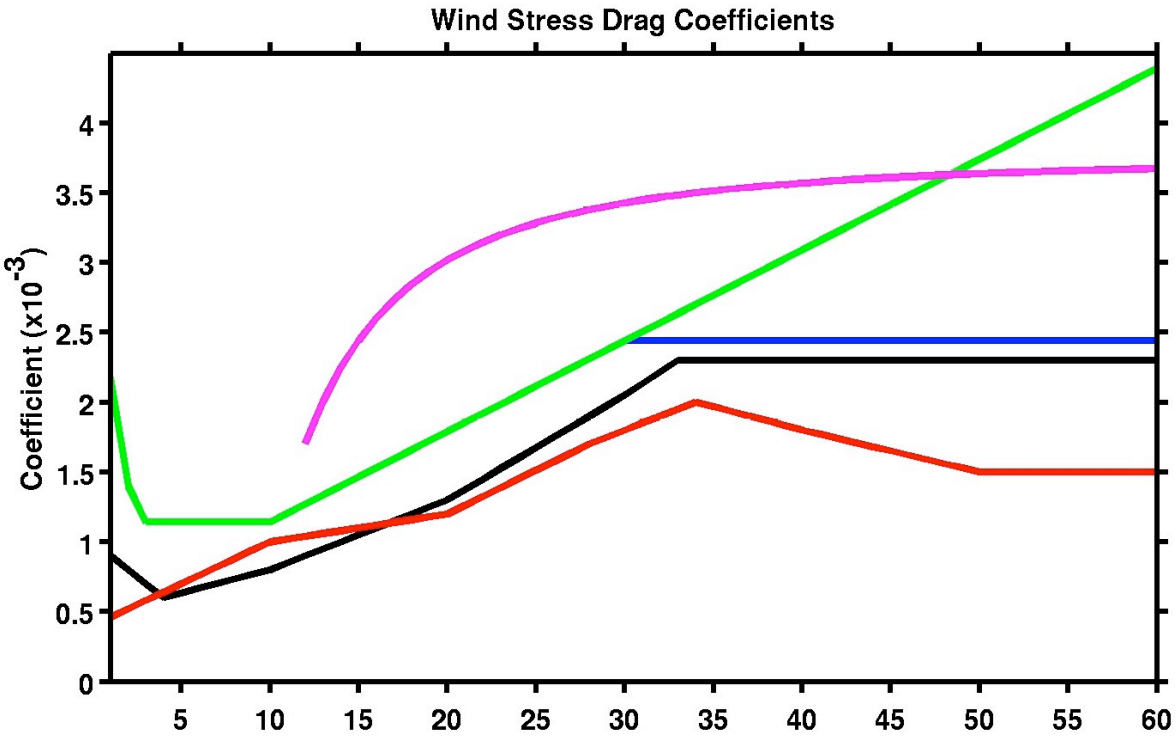


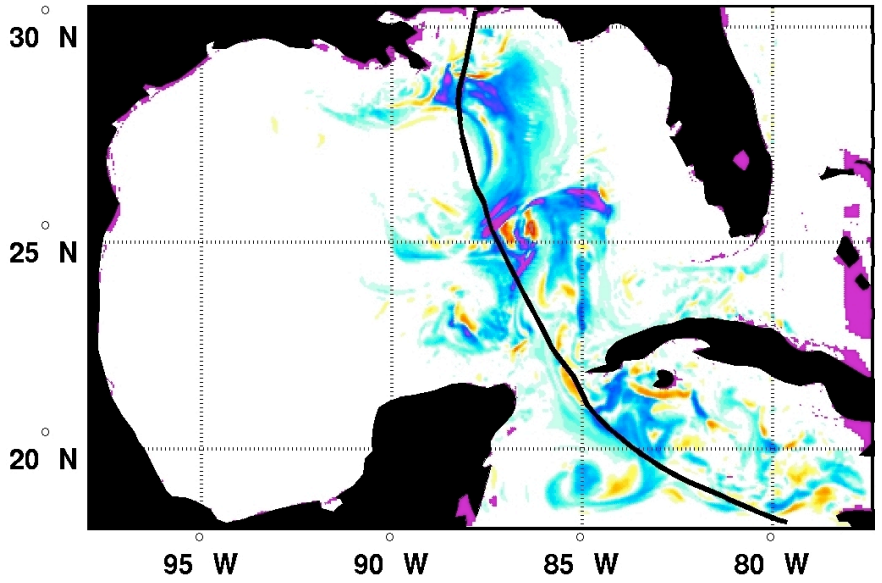
Initialization Problems

- So far, have only used fields from the U. S. Navy HYCOM-based nowcast-forecast system
  - Correctly locates major ocean features
  - Large cold bias prior to many storms
    - This causes ocean to overcool during TC simulations
  - Cold bias relatively small prior to Ivan
- Will soon evaluate the NOAA/NCEP/EMC HYCOM-based Atlantic Ocean system (RTOFS)


v (m/s), Observed
0
-50
-100
-150
-0.5
0
0.5
1
1.5
v (m/s), GOM1
0
-50
-100
-150
-0.5
0
0.5
1
1.5
Inertial Periods
1.5
1
0.5
0
-0.5
-1
-1.5


Correlation Coefficient
Standard deviation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.99
1
1.5
1
0.5
0
RMS
Legend:
Control experiment
Low horiz. resolution
Low vert. resolution
High vert. resolution
MY vertical mixing
GISS vertical mixing
Powell C_D
L&P C_D
L&P C_D (capped)
Shay and Jacob C_D


Wind Stress Drag Coefficients
Coefficient (x10^-3)
0
0.5
1
1.5
2
2.5
3
3.5
4
5
10
15
20
25
30
35
40
45
50
55
60


30° N
25° N
20° N
95° W
90° W
85° W
80° W

Model Attribute	Recommendations
Horizontal resolution	Up to 10 km is adequate (resolves scales of the eye and the eyewall)
Vertical resolution	Up to 10 m resolution in the ocean mixed layer is adequate
Wind stress drag coeff.	Donelan, Large & Pond (capped at high wind speed) are reasonable choices ($2.3\text{-}2.5 \times 10^{-3}$ at wind speeds > 30 m s^{-2})
Vertical mixing	KPP is optimum choice based on quality of momentum response at SEED moorings
Initialization	If the ocean initialization is poor, nothing else matters. This is true for both the location of ocean features and the accuracy of temperature, salinity, and density profiles in the upper ocean (e.g. the cold bias in the Navy product).

Future Plans

- **Extend results to other storms**
  - **Other ocean regions**
  - **Storms with high quality, three-dimensional targeted observations before, during, and after passage**
- **Evaluate HYCOM in coupled TC forecasts**
  - **Work with NOAA/AOML/HRD modelers to include HYCOM in their HWRF-X model and evaluate ocean model performance**